2004 DOE Hydrogen, Fuel Cells & Infrastructure Technologies Program Review Presentation

COST AND PERFORMANCE ENHANCEMENTS FOR A PEM FUEL CELL TURBOCOMPRESSOR

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PROJECT OBJECTIVES

- To assist the Department of Energy in the development of a low cost, reliable and high performance air compressor/expander
  - Technical Objective 1: Perform a turbocompressor systems PEM fuel cell trade study to determine the enhanced turbocompressor approach
  - Technical Objective 2: Using the results from technical objective 1, an enhanced turbocompressor will be fabricated. The design may be modified to match the flow requirements of a selected fuel cell system developer.
  - Technical Objective 3: Design a cost and performance enhanced compact motor and motor controller
  - Technical Objective 4: Turbocompressor/motor controller development

BUDGET

FY	Total ($)	DOE Share ($)	$Honeywell Share ($)
2004	$1.638M	$1.229M	$409K
2005	$1.415M	$1.061M	$354K
Total	**$3.053M**	**$2.290M**	**$763K**

TECHNICAL BARRIERS AND TARGETS

3.4.4. Technical Challenges: Transportation Propulsion Systems

- Air management for fuel cell systems is a challenge because today's compressor technologies are not suitable for automotive fuel cell applications.
- Finally, the size and weight of current fuel cell systems must be further reduced to meet the packaging requirements for automobiles. This applies not only to the fuel cell stack, but also to the ancillary components and major subsystems (e.g., fuel processor, compressor/expander, and sensors) making up the balance of power system.

3.4.4.2. Transportation Systems Barriers

- A. **Compressors/Expanders**. Automotive-type compressors/expanders that minimize parasitic power consumption and meet packaging and cost requirements are not available. To validate functionality in laboratory testing, current systems often use off-the-shelf compressors that are not specifically designed for fuel cell applications resulting in systems that are heavy, costly, and inefficient. Automotive-type compressors/expanders that meet the FreedomCAR program technical guidelines need to be engineered and integrated with the fuel cell and fuel processor so that the overall system meets packaging, cost, and performance requirements.

TECHNICAL BARRIERS AND TARGETS

Table 3.4.10. Technical Targets: Compressor/Expanders (C/E) for Transportation Fuel Cell Systems

Characteristic	Units	2003 Status	2005 Target	2010 Target
Input Power [a] at Full Load, 40°C Ambient Air				
Overall Motor/Motor Controller Conversion Efficiency, DC Input	%	85	85	85
50-kW_e Unit Reformate/Air w Expander	kW_e	7.0	5.0	4.4
50-kW_e Unit-Hydrogen/Air w Expander/wo Expander	kW_e	–	–	3.6/8.4
80-kW_e Unit-Hydrogen/Air w Expander/wo Expander	kW_e	–	–	5.8/13.2
160-kW_e Unit-Hydrogen/Air w Expander/wo Expander	kW_e	–	–	11.7/26.5

Input Power [b] at Part Load, 20°C Ambient Air
80-kW_e Demonstrator Only

% of Max Flow-Expander Inlet Temp.	Compressor Pressure (atm)	Expander Inlet Press.	Expander Use			
100/80°C	2.5	2.2	Yes/No	kW_e	–	4.8/12.3
75/65°C	2.0	1.8	Yes/No	kW_e	–	3.2/7.1
50/50°C	1.7	1.6	Yes/No	kW_e	–	1.6/3.3
30/50°C	1.4	1.3	Yes/No	kW_e	–	0.7/1.3
20/50°C	1.3	1.2	Yes/No	kW_e	–	0.5/0.7

Characteristic	Units	2003 Status	2005 Target	2010 Target
Efficiency at Full Flow (C/E Only) [c]				
50-kW_e Unit Reformate/Air-Compressor/Expander	%	70/80	80/80	80/80
50, 80, and 160-kW_e Unit Hydrogen/Air-Compressor/Expander	%	–	–	80/80
Efficiency at 20-25% of Full Flow (C/E Only) [c]				
50-kW_e Reformate/Air Unit-Compressor at 1.3 PR	%	60	60	60
50-kW_e Reformate/Air Unit-Expander at 1.2 PR	%	50	50	50
All other 50, 80, and 160-kW_e Units, Hydrogen/Air	%			
Compressor at 1.3 PR/Expander at 1.2 PR	%			60/50
System Volume [d]				
50-kW_e Unit-Reformate/Air	L	10-12	8-11	8-11
50-kW_e Unit Hydrogen/Air	L	–	–	8-11
80-kW_e Unit-Hydrogen/Air	L	–	–	15
160-kW_e Unit Hydrogen/Air	L	–	–	25
System Weight [d]				
50-kW_e Unit-Reformate/Air	kg	10-12	8-11	8-11
50-kW_e Unit-Hydrogen/Air	kg	–	–	8-11
80-kW_e Unit-Hydrogen/Air	kg	–	–	15
160-kW_e Unit-Hydrogen/Air	kg	–	–	25
System Cost [d,e]				
50-kW_e Unit-Reformate/Air	$	600	400	300
50-kW_e Unit-Hydrogen/Air	$	–	–	300
80-kW_e Unit-Hydrogen/Air	$	–	–	400
160-kW_e Unit-Hydrogen/Air	$	–	–	600
Turndown Ratio				
50-kW_e Unit-Reformate/Air		5	5-10	5-10
All other 50, 80, and 160-kW_e Units-Hydrogen/Air		–	–	10
Noise at Maximum Flow, dB(A) at 1 meter Excluding Air Flow Noise at Air Inlet and Exhaust				
50-kW_e Unit-Reformate/Air	dB(A) at 1 meter	>90	75	65
All other 50, 80, and 160-kW_e Units-Hydrogen/Air	dB(A) at	–	–	65

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APPROACH

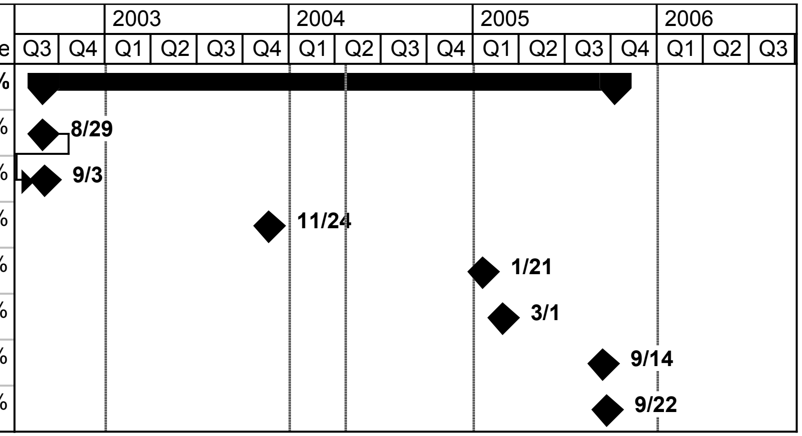
- Use automotive and aerospace turbomachinery technology for low cost and low weight/volume design
- Build upon previous turbocompressor experience use VNT™ variable nozzle turbine inlet geometry for improved performance and turndown ratio across the desired flow range
- Use a mixed flow type compressor for improved low flow performance
- Use contamination/oil free and zero maintenance compliant foil air bearings
- Use a modular approach to improve design flexibility
- Use a high efficiency, low cost two pole motor
- Use a low cost, no sensor required variable speed motor-controller topology design

PROJECT SAFETY

- The Honeywell Torrance site utilizes a variety of safety techniques in the design of equipment and analysis of potential hazards such as hazard & operability study (HAZOP), FMEA and what if analysis.
- Hazardous materials, processes and operation practice (form 3134) applies to the use of hazardous materials at Torrance. The new chemical approval request form is used to assure a knowledgeable Honeywell safety & environment person reviews each new chemical.
- All Torrance personnel receive CAL-OSHA regulatory compliance training each year. Additional specialized safety training is also given to certain technicians or crafts.
- Use of Honeywell experience and FMEA techniques to ensure a safe design
  - High speed device
    - Containment incorporated
  - High voltage device
    - Insulation incorporated

PROJECT TIMELINE

ID	WBS	Task Name	% Complete
2		**Milestones**	**41%**
3		DOE KICKOFF	100%
4	1.1	Honeywell IPDS LAUNCH	100%
5	2.0	Technical Objective #1: Trade Study	100%
6	3.0	Technical Objective #2: Enhanced Turl	0%
7	4.0	Technical Objective #3: Enhanced Mo	0%
8	5.0	Technical Objective #4: Turbocompre:	0%
9	6.0	Delivery to Fuel Cell Developer	0%



- Trade study used to determine specifications
- Complete turbocompressor, motor and motor controller fabrication and assembly by 2004
- Complete turbocompressor, motor and motor controller testing and documentation by 2005

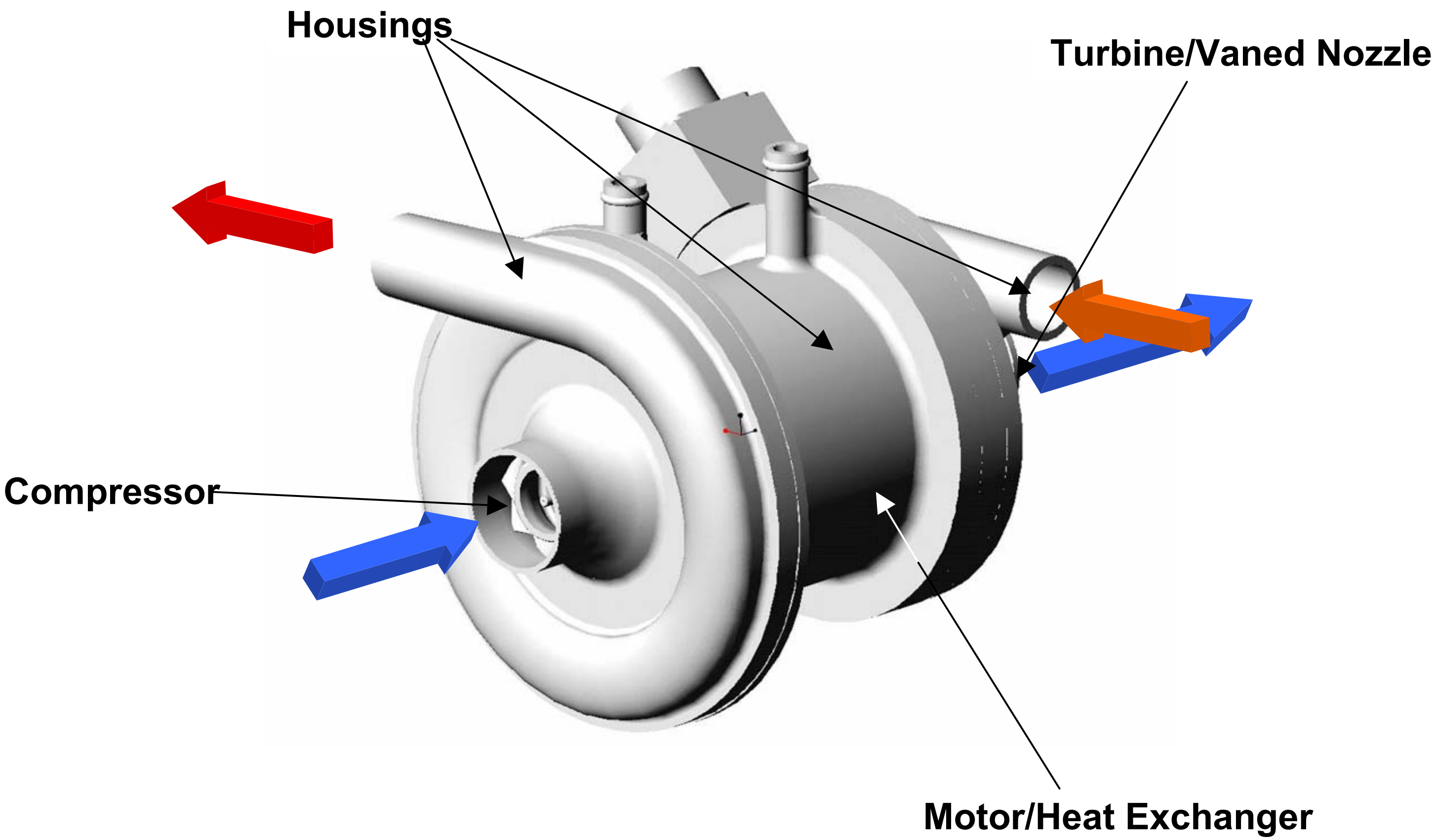
TECHNICAL ACCOMPLISHMENTS / PROGRESS

- Technical Objective #1: trade study
  - Interviews with various developers completed
    - Interviews determined priorities
      - Cost
      - Reliability/durability
      - Performance
      - Packaging
  - Comparison of 3 different turbocompressor configurations using the developer priorities above
  - Concluded that 2-wheel variable nozzle turbine is the preferred configuration

TECHNICAL ACCOMPLISHMENTS / PROGRESS

- Mixed flow compressor
- Radial inflow variable nozzle turbine (VNT™)
  - Use of the VNT™ from production Garrett Engine Boosting Systems turbocharger
- Air bearings
  - Honeywell developed
    - Increased performance over existing designs
    - Lower cost than existing designs
- Motor
  - New two-pole toothed design
- Motor controller
  - New design
- Liquid cooled motor and motor controller
- Scalability
  - Modular design

TECHNICAL ACCOMPLISHMENTS / PROGRESS



Size: 12L
Weight: 17kg

TECHNICAL ACCOMPLISHMENTS / PROGRESS

- Aerodynamics analysis completed
  - Compressor
    - Design meets pressure and flow targets
    - Design required to have excellent off-design performance that can affect efficiency
  - Turbine
    - Design meets pressure, flow and efficiency targets
    - Variable nozzle helps maximize turbine power
- Thermal analysis completed
  - Liquid and air adequate to cool the motor and bearings across the operating range
    - Model completed for various conditions

TECHNICAL ACCOMPLISHMENTS / PROGRESS

- Journal bearings
  - Load capacity exceeds requirements by a minimum margin of 2
  - Configuration reduces part count and cost
- Thrust bearings
  - Thrust load margin is over 3
  - Configuration reduces part count and cost

TECHNICAL ACCOMPLISHMENTS / PROGRESS

- Structural integrity
  - Turbine structural design complete
  - Compressor structural design complete
  - Analysis of fits completed
  - Pressure and containment analyses to be completed
  - Rotordynamic critical speed analysis completed

TECHNICAL ACCOMPLISHMENTS / PROGRESS

- Motor
  - Low cost
  - High reliability
    - Insulation
  - High efficiency
    - Stator material
    - Current density
    - Flux density
  - Compact and lightweight
  - Two pole design, 100krpm
  - High energy magnet

TECHNICAL ACCOMPLISHMENTS / PROGRESS

- Low cost
  - Sensorless controls - no hall sensors, cable and alignment procedure required
  - Off the shelf components
- Reliable
  - Sensorless controls
  - Integrated DSP
  - Environmental protection
- Performance
  - Sensorless control
  - Internal power absorption for regeneration on de-accelerations
  - 10% to 90% speed acceleration in < 1 second
- Various controls interfaces including can bus interface
- Built in test capabilities
- Low volume and weight

INTERACTIONS AND COLLABORATIONS

- Department of Energy, Washington D.C.
  - Patrick Davis and John Garbak
- Argonne National Laboratory
  - Dr. Rajesh Ahluwalia, Dr. Romesh Kumar and Mr. Bob sutton
- Fuel cell power system/automotive OEM's

FUTURE WORK

- Remainder of FY 2004:
  - Complete detailed design
  - Complete fabrication and assembly

- FY 2005:
  - Test turbocompressor and motor controller
  - Delivery of turbocompressor and motor controller
  - Final documentation

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QUESTIONS/COMMENTS?

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